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Design Improvement In Heavy Vehicle Truck Chassis By Analysis Using CAE Tools For Achieving Strength And Stability

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ABSTRACT

Chassis signifies the different frame parts of the vehicle on the other hand it also denotes the main structure of vehicle body. The chassis frame acts as the main supporting member for different components as well as the payload of the vehicle. It should be stiff adequate to resist shock, twist and vibrations in addition with some stresses cause by sudden activities like breaking, irregular road conditions and some forces obtain by components. So, strength and stiffness are important criteria while designing chassis. After analyzing different research studies, it should be found that there is the scope in modification of chassis with different factors like stress, deformation and weight by varying cross section in addition with materials. This research elaborates about structural analysis of heavy vehicle chassis under maximum load and dynamic analysis of modified chassis by calculating its natural frequencies to check failure due to resonance. For analysis purpose, dimensions of TATA 2518TC truck chassis is used by considering two main cross sections namely, "C" section with existing material that is Structural steel ST37 and "I" with AISI-4130 material. Three dimensional solid models of truck chassis was designed in SolidWorks software. The meshing part has been done on HyperWorks and finally finite element analysis was done on Ansys.

Keywords – Deformation, Stiffness, Strength, Stress, Weight

1. INTRODUCTION

The major challenge in today's ground vehicle industry is to overcome the increasing demands for higher performance, lower weight and longer life of components, all this at a reasonable cost [1]. The chassis is the backbone of vehicles. So, it is important to make chassis performance best. After analysis of different research works it was found that the chassis frame acts as the main supporting member for different components as well as the payload of the vehicle. It should be stiff adequate to resist shock, twist and vibrations in addition with some stresses cause by sudden activities like breaking, irregular road conditions and some forces obtain by components. So, strength and stiffness are important criteria while designing chassis. So, there is a need to analyze the chassis to improve these factors. Many research works have been done on chassis and after analyzing these studies some gaps were there considering strength and stiffness factors. Also some research works mostly try to cover these gaps but not give optimum results when compared with weight factor which is also important. Summarizing previous research works there is a scope to analyze chassis considering stress, stiffness and weight factors simultaneously.

The present work is done on heavy vehicle truck chassis (TATA 2518-TC) for elaborating the solution considering problem gaps. The present chassis used for this truck is of "C" section with Structural steel ST37 material. In this work, to increase the performance of chassis "C" section is replaced with "I" section chassis with AISI-4130 alloy steel material considering the standards for chassis. The work is divided into three parts. First part contains analytical study for design and comparison followed by modeling of both the chassis. Second part contains the static analysis to improve strength, stiffness by calculating stress and deformation and weight comparisons between both the chassis to select best chassis. Third part contains the dynamic analysis of modified chassis by calculating natural frequencies to avoid resonance.

2. LITERATURE SURVEY

D Andrew Pon Abraham, S John Alexis, C Naveen Kumar, G Rajkumar and R Kishore have work and discuss [1] "Design and analysis of LCV chassis (TATA 407)". This work includes designing and static analysis of TATA 407 LCV truck chassis. In this work, chassis with four different sections namely, C (existing), Double C, I and Box type have been used for static analysis with two different materials namely, S-

Glass and Structural steel. They have discuss that Box section with S-Glass material have better results in stress and deformation compared with existing “C” section chassis. There was a reduction in weight possible up to 31%.

Akash Singh Patel and Atul Srivastava have worked on [2] “Modeling, analysis and optimization of TATA truck chassis using CAE tool”. In this work, there was a comparison take place between four different materials namely, Structural steel, grey cast iron, AISI-4130 alloy steel and ASTM A710 Steel Grade of chassis using only “C” section. The parts were made and assembled in CATIA and static analysis was done in Ansys 14.0. For comparison they used deformation results of each material. They conclude that chassis with AISI-4130 shows best response under high weight condition compared with existing material.

P. Bhowmick, D. Malhotra, P. Agarwal and K. Ravi have researched on [3] “Design and analysis of pick-up truck chassis”. In this work they elaborate about maximum deflection and dynamic conditions under vibrations as main factors for the chassis analysis. They compare chassis with four different materials by Finite Element Analysis using Ansys tool and select the chassis which gives less deformation. On this modified chassis harmonic analysis was done for comparing frequencies to avoid resonance and it was found that all natural frequencies come under 100Hzs which concludes chassis was dynamically stable.

Arun G V, Kishore Kumar K and Velmurugan S have studied [4] “Structural Analysis of Chassis using AISI 4130 and AA 7068”. This research states that AA 7068 material have better response than AISI 4130 material chassis. Also weight was reduced by 50%. It result the reduction in weight of chassis.

Ranjith Kumar V, Dharani Dharan R, Pradeep Kannan S S and Balaji N have studied [5] “Design and analysis of truck chassis”. This work includes the designing and static analysis of truck. In this work, chassis with same cross section but different materials have been compared to improve performance. Weight, stiffness and strength these were main factors considered for comparison purpose. The weight of chassis reduces by 10% and gives less deformation under 15tons loading conditions.

Ojo Kurdi , Roslan Abdul Rahman and Pakharudin Mohd Samin have researched and discuss [6] “Optimization of Heavy Duty Truck Chassis Design by Considering Torsional Stiffness and Mass of the Structure”. The torsional stiffness of chassis can be improved by making shape changes in the chassis either by decreasing thickness or by section replacement.

3. PROBLEM STATEMENT

The chassis acts as the main platform for different parts of vehicle and also connections between upper and lower part of the vehicle. The whole weight of the vehicle acts on the chassis considered as main frame. Specific to truck, due to huge amount of GVW (Gross Vehicle Weight) it is important to analyze and made modifications in chassis to improve vehicle stability and performance. The chassis performance mostly depends on four main factors namely strength, stiffness, deformation and weight. The past studies made on this work elaborates that in India most of the truck manufacturers uses chassis made of “C” section and Structural steel as material. So, to improve such type of chassis many research works have been done but not matches the desired output. There is a need to replace “C” section with another section and in that case according to literature study “I” section is best suitable. It was found that due to weight factor only replacement study not a satisfied solution. Also, if first two gaps solved there is a need to check improved chassis in dynamic conditions to avoid failure. Summarized to literature survey, research works done to improve existing chassis three main gaps were found. First replacement in “C” section, second replacement in existing material and geometry considering weight factor and third check dynamic behavior of chassis is important.

4. STRUCTURE OF ARTIFICIAL NEURAL NETWORKS

Model No. = LPT 2518 TC (TATA) [2]
Capacity of Truck = Kerb Weight(Kgs) + Payload(Kgs)
= 5750 + 19250
= 25000 kg
= 25000 * 9.81
= 245250 N.

The above mention calculation is for the standard purpose only but according to the market conditions the weight may vary many times. So, for factor of safety purpose there is a increment in standard weight by 25% approximately.

Capacity of Truck with 1.25% = 245250 * 1.25 N
= 306562 N

Total Load acting on the Chassis is 306562 N. Now, all parts of the chassis are made from “C” channel with specifications 285mm x 65mm x 7mm. Each Truck chassis has two beams. So load acting on each beam is half of the Total load acting on the chassis.

Load acting on the single frame = Total load acting on the chassis / 2

= 306562 /2

=153281 N / Beam.

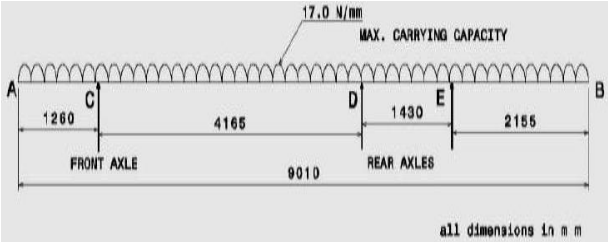

Fig. 1. Total load generated on the beam

- Section of Modules around the X – X axis:-
  $Z_{XX} = (I_{XX} / y)$ [2]....Eq. (1)
- Stress produced on the beam :-
  $M/I = \sigma/y = E/R$ [2]….Eq. (2)
  $\sigma = (M / Z_{XX})$ [2]….Eq. (3)
- Maximum Deflection produced on the Beam
  $Y_{max} = (-9.0976 * 10^{13} / E\ I)$ [2]…..Eq. (4)

5. DIMENSIONS AND MATERIALS

5.1 "C" Section

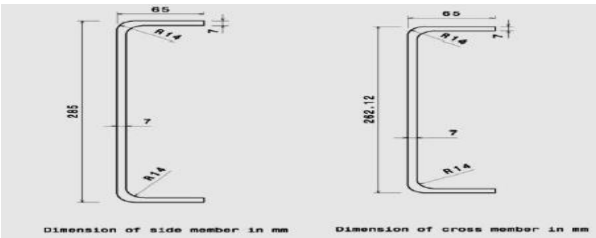

Fig. 2. From LR (a) C section of side members (b) C section of cross members

5.2 "I" Section

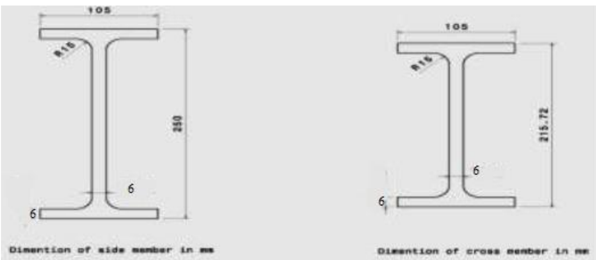

Fig. 3. From LR (a) I section of side members (b) I section of cross members

5.3 Material Selections

Table 1: Material properties

Material	Modulus of elasticity (GPa)	Density (Kg/m^3)	Tensile strength (MPa)	Yeield strength (MPa)
ST-37	210	7850	460	260
AISI-4130	260	7798	1030	910

A] ST-37 STEEL FOR "C" SECTION: IS - 9345.
B] AISI-4130 FOR "I" SECTION: IS-9345.

Fig. 4 Chassis model in SolidWorks

6. METHODOLOGY

- Collect dimensional data of TATA LPT 2518 TC chassis frame.
- Modeling followed by assembly in SolidWorks.
- Meshing should be done on HyperWorks with 20mm element size.
- Using FEA concept static analysis done in ANSYS by checking all parameters whether they are within permissible limit or not for selected materials.
- Dynamic analysis done to check resonance effect to avoid failure.

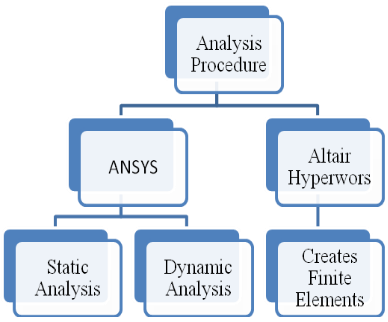

Fig.5. Methodology for Analysis

7. FINITE ELEMENT ANALYSIS

This section is proceeding in three parts as first part elaborates about mesh generation, second part contain static analysis and finally dynamic analysis have been taken.

7.1 Meshing

For meshing generation, size of element is 20mm and this is done using HyperWorks software.

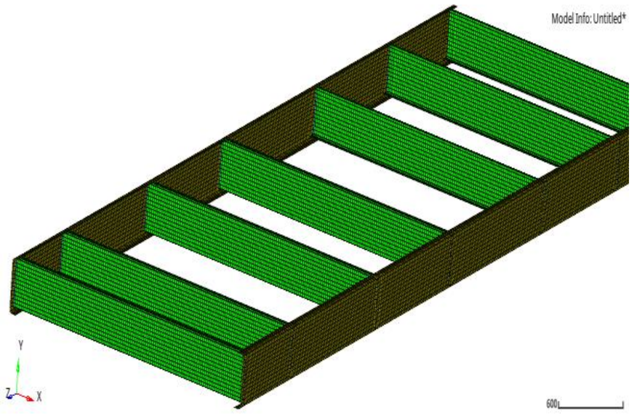

Fig. 6. Meshing

The shape of the mesh generated is rectangular shape.

7.2 Static Analysis

The effects of load on physical structure should be determined by using static analysis.

7.2.1 Boundary conditions: The fixed supports are the positions where leaf spring should be attached.

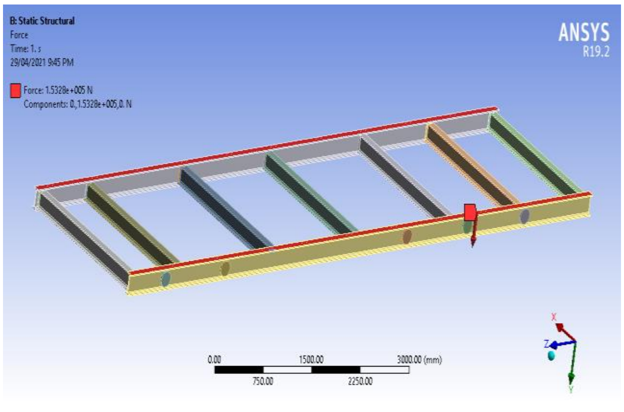

Fig. 7. Fixed supports and UDL

UDL acting on either side = 153281 N.

7.2.2 Static Analysis of "C" Section: (a) Maximum Principal Stress: The maximum principal stress occurs at 202.66 MPa.

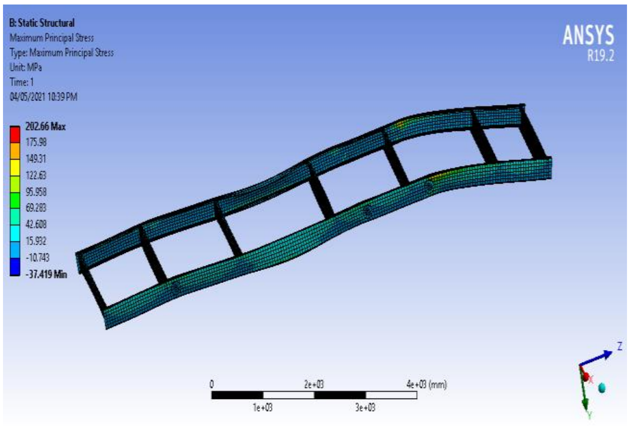

Fig 8. Maximum Principal Stress

b) Equivalent (Von-Mises) Stress: The maximum Von-Mises stress occurs at 178.55MPa.

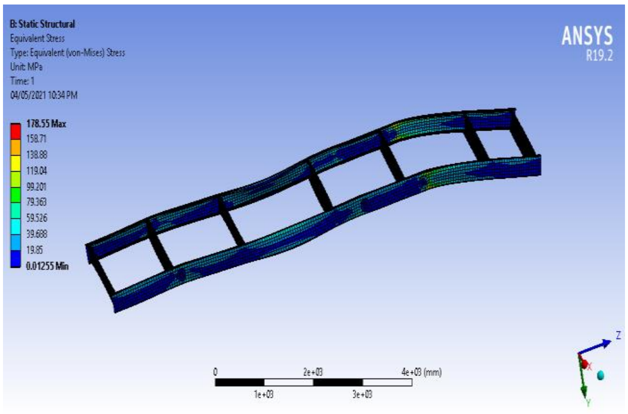

Fig 9. Maximum Equivalent (Von-Mises) Stress

c) Maximum Shear Stress: The maximum principal stress occurs at 93.861MPa.

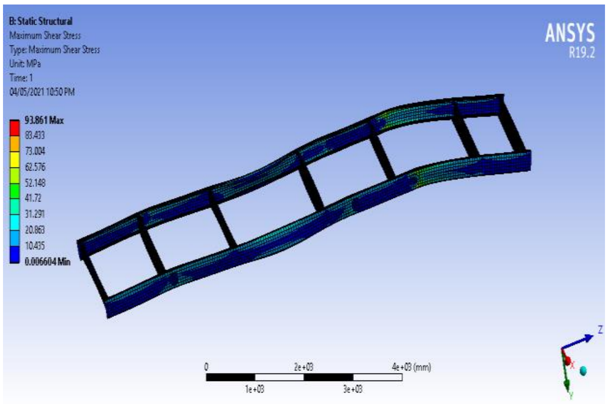

Fig 10. Maximum Shear Stress

d) Total Deformation: The total deformation occurs at the rear extreme which is 7.8441mm.

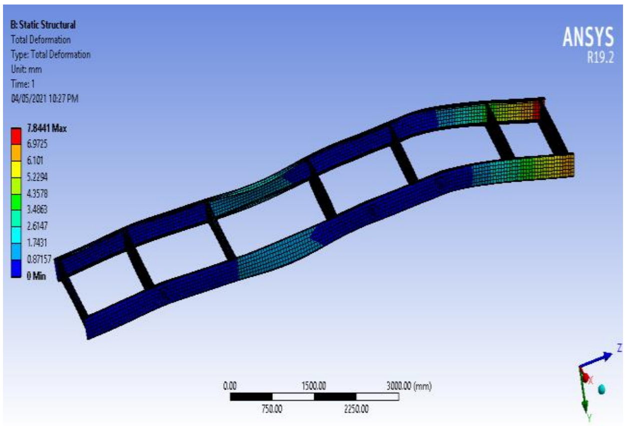

Fig 11 Total Deformation

7.2.3 Static Analysis of "I" Section: a) Maximum Principal Stress: The maximum principal stress occurs at 159.86MPa.

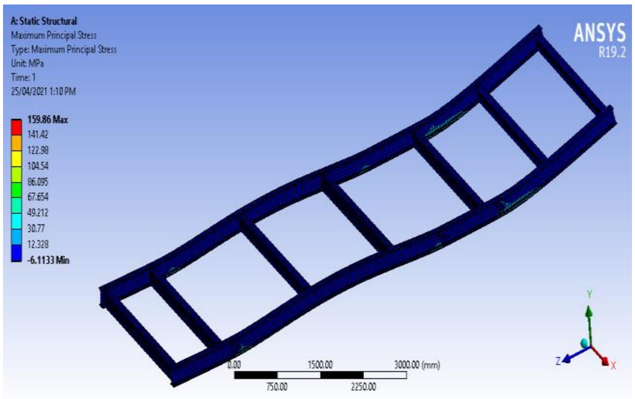

Fig 12 Maximum Principal Stress

b) Equivalent (Von-Mises) Stress: The maximum Von-Mises stress occurs at 149.58MPa.

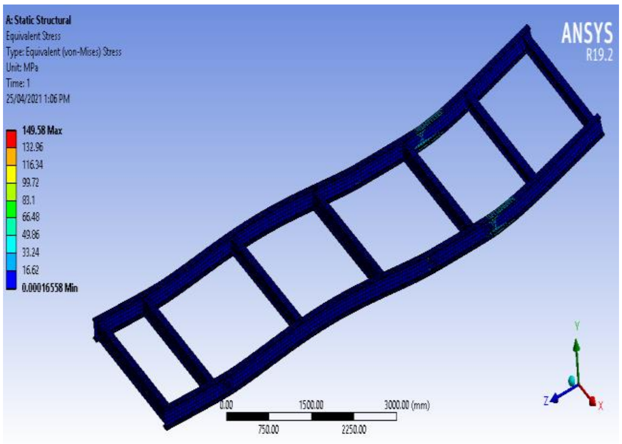

Fig 13 Maximum Equivalent (Von-Mises) Stress

c) Maximum Shear Stress: The maximum principal stress occurs at 84.727MPa.

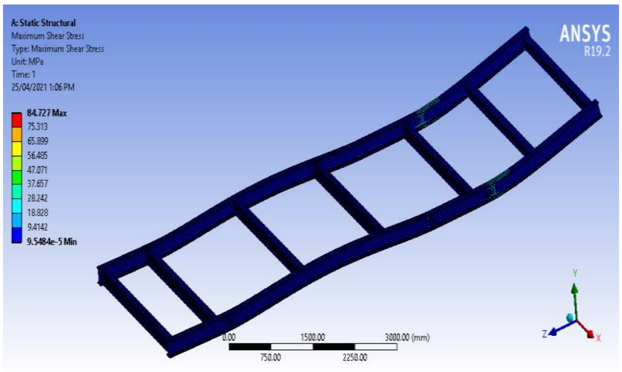

Fig 14 Maximum Shear Stress

d) Total Deformation : The total deformation occurs at the rear extreme which is 3.68mm.

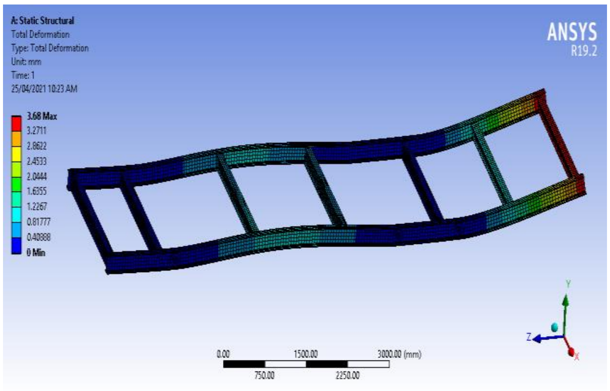

Fig 15 Total Deformation

7.3 Dynamic Analysis`

To find natural frequencies and mode shapes modal analysis have been done. Theses natural frequencies then compared with the vibration frequency of truck.

7.3.1 Various mode shapes and their frequencies:

1) The 1st mode occurs at frequency 15.529Hz having 2.254mm maximum deformation . Now, specific to the shape, there is a change in mode shape at extreme part of chassis. The mode shape changes in X-axis.

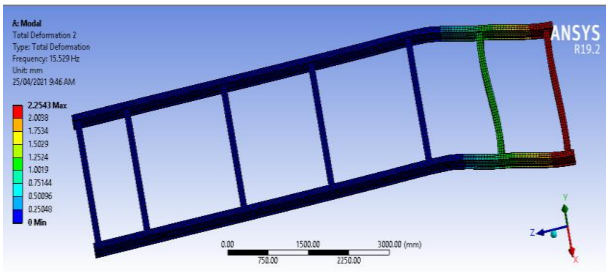

Fig 16 Total Deformation by 15.529Hz Frequency

2) The 2st mode occurs at frequency 20.147Hz having 1.917mm maximum deformation. . Now, specific to the shape, there is a change in mode shape at 3rd cross member of chassis. The mode shape changes in X-axis.

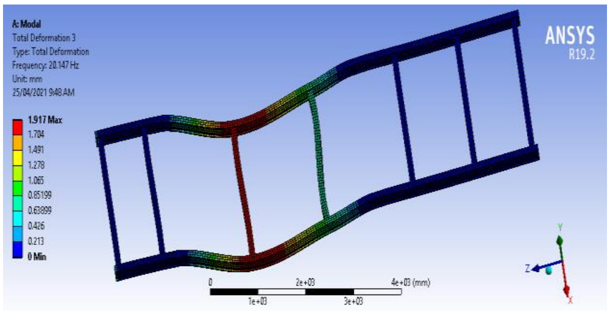

Fig 17. Total Deformation by 20.147Hz Frequency

3) The 3rd mode occurs at frequency 33.824Hz having 2.7154mm maximum deformation. . Now, specific to the shape, there is a change in mode shape at front part of chassis. The mode shape changes in Y-axis.

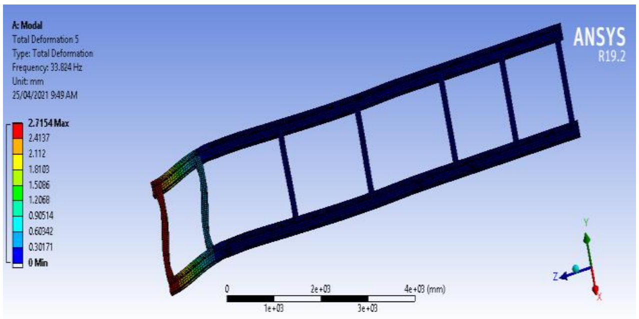

Fig 18. Total Deformation by 33.824Hz Frequency

4) The 4th mode occurs at frequency 42.787Hz having 2.0557mm maximum deformation. Now, specific to the shape, there is a change in mode shape at 4th cross member of chassis. The mode shape changes in X-axis direction.

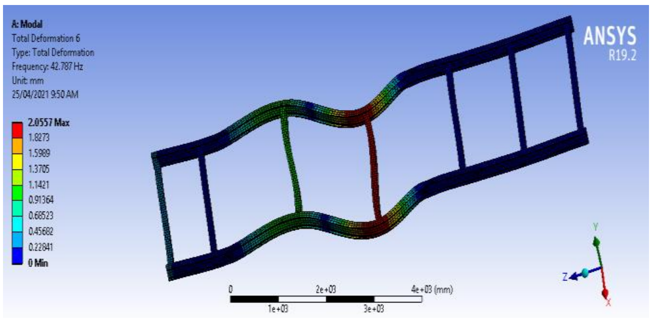

Fig 19. Total Deformation by 42.787Hz Frequency

5) The 5th mode occurs at frequency 48.88Hz having 3.4195mm maximum deformation. Now, specific to the shape, there is a change in mode shape at extreme part of chassis. The mode shape twists about Z-axis.

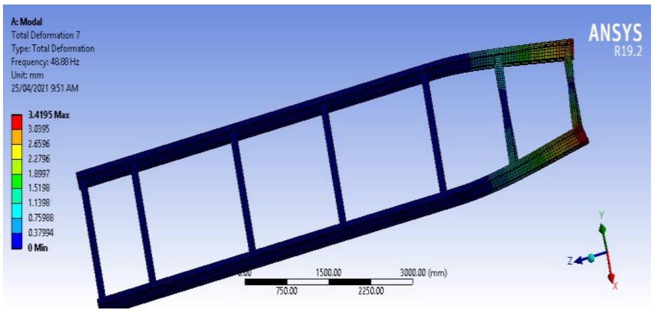

Fig 20. Total Deformation by 48.88Hz Frequency

6) The 8th mode occurs at frequency 53.748Hz having 4.3907mm maximum deformation . Now, specific to the shape, there is a change in mode shape at extreme part of chassis. The mode shape changes in X-axis direction.

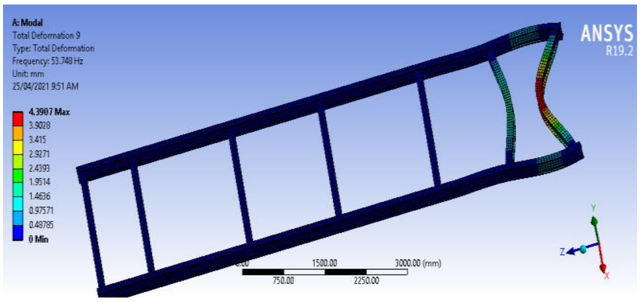

Fig 21 Total Deformation by 53.748Hz Frequency

7) The 9th mode occurs at frequency 54.793Hz having 2.254mm maximum deformation . Now, specific to the shape, there is a change in mode shape at middle part of chassis. The mode shape changes in Z-axis direction.

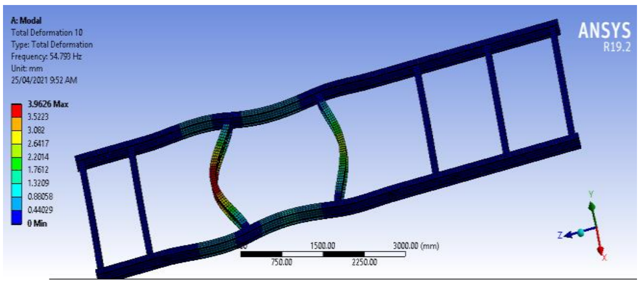

Fig 22. Total Deformation by 54.793Hz Frequency

8) The 10th mode occurs at frequency 56.02Hz having 4.6975mm maximum deformation. Now, specific to the shape, there is a change in mode shape at front part of chassis. The mode shape changes in X-axis direction.

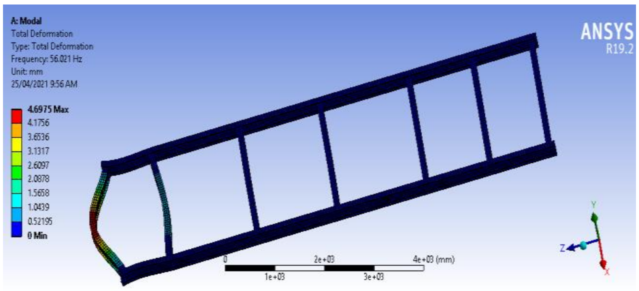

Fig 23. Total Deformation by 56.02Hz Frequency

8. RESULTS AND DISCUSSION

8.1 Analytical results

The stress generated in "C" section beam is 202.66 MPa which produces 14.839mm deflection in the chassis. Similarly, in "I" section chassis the stress value is 140.89MPa which produces 8.845mm deflection. So, we can conclude that "I" section having less deflection as well as stress than "C' section chassis

Table 2: Analytical results

Type of section	Stress (MPa)	Deformation (mm)
"C" Section chassis with (Steel ST-37)	206.66	14.839
"I" Section chassis (AISI-4130)	140.89	8.854

8.2 Static analysis

Table 3: Static analysis

Type of Section	Maximum Principal Stress (MPa)	Equivalent (Von-Mises) Stress (MPa)	Maxim-um Shear Stress (MPa)	Total Deformat-ion (mm)
"C" section Chassis (Structural Steel ST 37)	202.66	178.55	93.861	7.8440
"I" section Chassis(AISI-4130)	159.86	149.58	84.727	3.6800

By comparing the above results, the "I" section chassis with material "AISI-4130" got less deformation and stress, comparing to "C" section chassis with same loading conditions.

8.3 Dynamic analysis

Table 4: Natural Frequencies

Natural Frequencies (Hz)	Deformation (mm)
15.529	2.154
20.147	1.971
33.824	2.715
42.786	2.0557
48.88	3.419
53.748	4.390
54.793	3.960
56.021	4.69

The frequency of vibrations produced by the vehicle engine is above 60Hz [3]. Now, by comparing these natural frequencies of the truck chassis with the frequency of vibrations produced by engine, it is found that no such frequency of chassis matches with the frequency of vehicle engine. So, there is no chance of resonance occurrence in "I" section chassis. Hence, "I" section chassis is safe in dynamic loading conditions.

9. CONCLUSION

Existing "C" section chassis is replaced by "I" section with modifications made by decreasing height, thickness and cross section of chassis. Due to replacement and material changing there is a decrement possible in weight by 10%.

A comparison is made between chassis section in terms of deformation and stresses, to select the best one. From the results, it is observed that the "I" section have more strength than existing "C" section chassis. The "I" section is having least deformation i.e., 3.6800 mm and decrement in the stresses than existing "C" section. So, "I" section with AISI-4130 material is suitable for the heavy trucks. Finally the analysis using different cross section has been successfully accomplished.

After this the dynamic analysis is done with "I" section chassis to check resonance and it is found that the natural frequencies of chassis not matches with the frequency of truck which is 60Hz and our natural frequencies of chassis are under 60Hz so there is a no chance for resonance and failure of "I" section chassis.

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